

3.4 Research and Monitoring Action Plan

Background

Many research and monitoring issues were identified by the ONMS and the public during the FGBNMS management plan review. Public scoping comments highlighted several concerns for the overall health of the sanctuary, including potential impacts to sanctuary resources from fishing and diving activities, invasive species, marine debris, climate change, and pollutant discharge. Of particular interest is the ecological connectivity of FGBNMS and other banks in the northwestern Gulf of Mexico. These concerns can be addressed with continued characterization, research, and monitoring in FGBNMS and integrated into the six strategies outlined below.

Purpose

The purpose of the Research and Monitoring Action Plan (RMAP) is to provide a guide for research activities at FGBNMS, and throughout the region, that will inform management and protection of sanctuary resources and the reefs and banks of the northwestern Gulf of Mexico that are ecologically connected to the sanctuary. The RMAP contributes to the attainment of the following FGBNMS goals: *Goal 1*) Protect, maintain, and where appropriate, restore and enhance the resources and qualities of Flower Garden Banks National Marine Sanctuary and the ecosystem that supports it; *Goal 2*) Support, promote, and coordinate characterization, research, and monitoring of FGBNMS and the regional environment to inform conservation and protection; and *Goal 6*) Promote ecosystem-based management of the FGBNMS regional environment.

Strategies and Activities

The RMAP has five strategies and associated activities to guide research and monitoring efforts.

RM.1 – Investigate ecosystem processes.

- Activity 1.1 Investigate the reproductive ecology of marine organisms.
- Activity 1.2 Investigate recruitment dynamics of marine fishes and coral reef invertebrates.
- Activity 1.3 Investigate trophic interactions within the FGBNMS ecosystem.
- Activity 1.4 Investigate the biological and physical connectivity among the banks of the northwestern Gulf of Mexico and the wider Gulf region.

RM.2 – Assess and characterize sanctuary resources.

- Activity 2.1 Conduct mapping at various scales throughout FGBNMS and other banks in the northwestern Gulf of Mexico.
- Activity 2.2 Document the range of biodiversity found within the sanctuary and surrounding areas.
- Activity 2.3 Conduct geological characterization of sanctuary resources.
- Activity 2.4 Conduct regional oceanographic characterizations.

RM.3 – Maintain and enhance monitoring programs.

- Activity 3.1 Maintain the long-term monitoring program and databases of coral ecosystems within the sanctuary.
- Activity 3.2 Enhance and expand the long-term monitoring program within the sanctuary and surrounding banks.
- Activity 3.3 Monitor sanctuary resources for human health concerns.

Activity 3.4 Continue to conduct monitoring in response to natural and human-induced events.

Activity 3.5 Establish FGBNMS as a sentinel site to monitor climate change and ocean acidification.

RM.4 – Implement a process to evaluate the impacts of fishing and diving.

Activity 4.1 Establish a working group of the sanctuary advisory council to comprehensively examine the concept of and develop potential designs for research areas.

Activity 4.2 Establish and implement a biological resource monitoring program within the sanctuary to establish baseline data for fish and benthic communities prior to experimental manipulation.

Activity 4.3 Develop and implement an analysis to determine potential socioeconomic impacts of implementing a research (experimental closure) area within FGBNMS.

Activity 4.4 Conduct an analysis of possible alternatives for the establishment of a research design to determine impacts of fishing and diving.

RM.5 – Identify and evaluate ongoing and potential threats to sanctuary resources.

Activity 5.1 Assess the accumulation and impacts of marine debris.

Activity 5.2 Continue to identify presence and behavior of invasive species.

RM.6 – Develop partnerships with local, national, and international researchers and organizations to enhance sanctuary research and monitoring programs.

Activity 6.1 Collaborate with national and international scientists, agencies and institutions to conduct research on priority issues.

RM.1 Investigate ecosystem processes.

FGBNMS will encourage investigations of ecosystem processes to better understand the species, relationships, and processes that are critical to sustaining the ecological functioning of sanctuary resources. Ecosystem processes of significant interest include reproductive ecology, recruitment dynamics of fish and invertebrates, trophic interactions and biological and physical connectivity among the banks of the northwestern Gulf of Mexico. By increasing our understanding of this connectivity, we will be able to assess the overall ecosystem health of the banks and potentially, the wider Gulf region.

Activity 1.1 Investigate the reproductive ecology of marine organisms.

Understanding the reproductive ecology of coral reef organisms is an ongoing effort, especially in regards to non-coral species, such as sponges and other invertebrates, and associated fish populations. We presently lack a complete understanding of the role of the Flower Garden and Stetson Banks in contributing to the reproductive output of marine fishes and invertebrates within the sanctuary and throughout the wider Gulf region.

Studies and observations are ongoing on the reproductive timing and behavior of corals, sponges, other invertebrates, and grouper in FGBNMS. Reproductive studies, to date, have primarily been limited to the coral reef cap, but will be expanded to include deeper water habitat within the sanctuary, as well as other banks in the region.

Recent reports have also identified potential spawning aggregations of Wahoo at West Flower Garden Bank, Silky Shark at Stetson Bank, and Marbled Grouper at Geyer Bank. Research efforts will focus on these newly documented aggregations to reconcile the general lack of data on these species and their specific use of the habitats within FGBNMS region. Partnerships will be sought to provide the expertise and funding to fully investigate these areas of interest.

Activity 1.2 Investigate recruitment dynamics of marine fishes and coral reef invertebrates.

Larval fish and invertebrate recruitment to the Flower Garden Banks, Stetson Bank and other banks in the northwestern Gulf of Mexico is an important diagnostic for assessing the overall ecosystem functioning of the reefs. Partnerships will be sought to provide the expertise and funding for recruitment surveys that will be conducted over the Flower Garden Banks and other nearby banks. These studies will link fish recruitment dynamics to habitat characteristics, including benthic species composition, structural complexity, as well as oceanographic parameters, such as water temperature, salinity, and current direction.

Activity 1.3 Investigate trophic interactions within the FGBNMS ecosystem.

Trophic interactions are commonly studied through feeding (gut content) analysis of fishes and the use of dietary tracers (e.g., stable isotopes). Understanding the trophic relationships of organisms within coral reef communities and associated communities within and adjacent to the sanctuary will allow sanctuary management to fully account for the connections among the various habitats. Connections highlighted through the food web will inform management decisions regarding the multiple habitats in use by organisms, as well as potential human health concerns (see Activity 3.3). To begin developing a trophic interaction model, organisms will be sampled at all trophic levels. Partnerships will be sought to provide the expertise and funding for trophic studies at FGBNMS. Initial investigations have been conducted with research partners and external funding sources.

Activity 1.4 Investigate the biological and physical connectivity among the banks of the northwestern Gulf of Mexico and the wider Gulf region.

Studies will be conducted to ascertain the level of biological and physical connectivity on a regional basis. Biological connectivity can be described at various levels: genetic, larval recruitment and dispersal, and adult movement patterns and habitat use. A broad array of techniques will be utilized to investigate these questions, including genetic analysis, quantitative and qualitative analysis of population structure, larval recruitment and dispersal studies, trophic interactions analysis, acoustic and satellite tagging of benthic, pelagic and highly migratory species, modeling island hopping or the use of habitat highways, and direct observation. Physical connectivity can be described through detailed mapping of the seafloor, groundtruthing and habitat characterizations. Physical features with similar structural components and depth profiles may support biological connectivity among the banks in the northwestern Gulf of Mexico.

Since 1997, FGBNMS staff, with the help of partners, have been actively mapping features on the seafloor of the northwestern Gulf of Mexico with high-resolution multi-beam and backscatter technologies. From this mapping effort, sanctuary staff have identified at least 31 separate banks or high relief features in the region that exhibit similarities in depth and physical habitat structure and contribute to an overall connectivity among banks in the region.

FGBNMS and partners will continue to conduct groundtruthing surveys, produce habitat characterization maps, and inventory biological components. FGBNMS will pursue partnerships to provide the expertise and funding for genetic analysis, larval recruitment and dispersal studies, trophic interactions, acoustic and satellite tagging, and modeling.

RM.2 Assess and characterize sanctuary resources.

Baseline characterization studies were first conducted in the region in the mid- and late 1970s and early 1980s by the Bureau of Land Management (which became the responsibility of the Minerals Management Service). These investigations were continued by the FGBNMS research team in the early 1990s and are ongoing. As new technologies and capabilities are developed, updated studies will provide researchers and management with higher resolution information upon which to base adaptive management decisions and research priorities.

Activity 2.1 Conduct mapping at various scales throughout FGBNMS and other banks in the northwestern Gulf of Mexico.

The FGBNMS research team will collaborate with partners to utilize the R/V *Manta* and other NOAA vessels for continued mapping efforts in the region. FGBNMS, U.S. Geological Survey, University of New Hampshire, NOAA Office of Exploration, Minerals Management Service, and NOAA Office of Marine and Aviation Operations have collaborated since 1997 to conduct high resolution multi-beam surveys in the northwestern Gulf of Mexico, covering over 4000 km² of seafloor. Despite the scale of previous efforts, mapping of more seafloor at higher resolution continues to be a priority to help determine the extent of biological and geological habitat and emergent features. Shelf-edge banks in the northwestern Gulf of Mexico are specifically targeted as they represent Essential Fish Habitat (EFH), and have been designated as Habitat Areas of Particular Concern by the Gulf of Mexico Fishery Management Council. Mapping will continue to be conducted in sanctuary areas opportunistically.

As new information and details are obtained through manned submersible, ROV and SCUBA surveys, higher resolution and more accurate biological and structural habitat maps of the region will be developed. The initial habitat zonation maps for the region were developed from studies conducted in the 1970s and 1980s (Rezak et al. 1985). These initial maps provided the current efforts with a solid baseline of data upon which to build biological and geological datasets. As a result of increased resolution of mapping, photography, videography, sampling capabilities, and underwater tracking, the original biological maps have been updated by the FGBNMS research team. However, the biological habitat maps need to be groundtruthed. These verification efforts will continue as funding permits.

Activity 2.2 Document the range of biodiversity found within the sanctuary and surrounding areas.

Research efforts within the sanctuary will continue to identify previously undocumented species that are encountered. Range extensions of known species and new species descriptions have been recorded for FGBNMS. For instance, Roper's inshore squid (DeBose and Vecchione 2005) and the Caribbean two-spot octopus were documented in FGBNMS as range extensions for these species. Two species of serranids, Nassau Grouper (*Epinephelus striatus*) and Goliath Grouper (*Epinephelus itajara*), that were previously unreported at FGBNMS have been documented since 2004. Three new (previously undescribed) species have also been reported from FGBNMS: the Mardi Gras Wrasse

(*Halichoeres bureki*; Weaver and Rocha 2007), a red algae (Rhodophyta: *Martensia hickersonii*; Fredericq 2005), and a snapping shrimp (*Alpheus hortensis*; Wicksten and McClure 2003).

Activity 2.3 Conduct geological characterization of sanctuary resources.

Sanctuary staff will pursue partnerships and funding to conduct geological characterizations to determine the origin and history of the reefs of FGBNMS and place the deeper water areas into historical perspective. Deep coring (approximately 60ft/18m depth) studies will be conducted, as funding allows, to determine the extent and age of the coral caps at East and West Flower Garden Banks. Targeted coring studies on the coral cap will also be conducted, as funding allows, to describe *Acropora*'s natural history and role in the development of FGBNMS coral reefs. Paleoclimatological studies have been conducted at FGBNMS, but do not reach back through the historical records beyond several hundred years. If funding allows, shallow cores from deepwater areas will be obtained using technical divers to determine substrate type and geological history, especially relating to the historical shoreline underlying the biological communities of the sanctuary.

Activity 2.4 Conduct regional oceanographic characterizations.

The movement and quality of regional water masses play a fundamental role in the ecosystem of FGBNMS. Sanctuary staff will pursue funding opportunities to enhance *in situ* oceanographic instrumentation to provide increased capabilities for real time weather observations and forecasting throughout the region. Texas A&M University's Geochemical and Environmental Research Group (GERG) has maintained two Texas Automated Buoy System (TABS) buoys in the vicinity of FGBNMS as a component of a FGBNMS Joint Industry Project coordinated by MMS. These buoys provide real-time temperature, current, and wind measurements. *In situ* water quality instruments have been placed on the sea floor at each bank to measure temperature and salinity. Additional water quality parameters, such as turbidity, dissolved oxygen, pH, and chlorophyll-a, will be added to the instrument arrays as funding allows. Sanctuary staff will pursue opportunities to analyze existing, archived datasets to model oceanic processes affecting the sanctuary and other banks in the northwestern Gulf of Mexico.

RM.3 Maintain and enhance monitoring programs.

Ecosystem health is reflective of a system's ability to resist, and be resilient following environmental and anthropogenic disturbances. The FGBNMS ecosystem includes both the benthic components and water masses surrounding the physical structure of the banks. Long-term monitoring of the coral cap regions of the sanctuary is designed to examine the health of the reef through direct measurements of percent cover of benthic organisms, occurrence of coral mortality, coral diversity, and growth or retreat of coral tissue. By tracking changes in these parameters from year to year, the monitoring acts as an early warning system for sanctuary management to take steps to prevent any further loss of health on the reef. Water quality monitoring also aids sanctuary management in making informed decisions surrounding the offshore reefs of FGBNMS. Expanding the sanctuary monitoring effort to include the pelagic and deeper regions of the sanctuary, along with additional water quality measurements, will enable sanctuary management to incorporate more ecosystem-wide parameters in the determination of overall ecosystem health and potential threats and concerns. With the recent discovery of ciguatera¹ in fishes from the waters in and around the sanctuary, monitoring aspects of the environment that may affect human health is of particular importance. An

¹ A potent neurotoxin that is secreted by a dinoflagellate and can accumulate in the flesh of certain marine fish, such as grouper or snapper. It causes ciguatera poisoning in those who eat fish that have concentrated toxic levels.

efficient and effective monitoring program is required for the adaptive management of these offshore coral communities. FGBNMS will pursue expertise and funding to address this more thoroughly.

Activity 3.1 Maintain the long-term monitoring program and databases of coral ecosystems within the sanctuary.

FGBNMS will continue to sponsor and/or conduct the long-term monitoring efforts at East and West Flower Garden and Stetson Banks. Long-term monitoring of East and West Flower Garden Banks has been conducted since 1988 through contracting and in partnership with MMS. Sanctuary staff assumed responsibility for the Flower Garden Banks long-term monitoring project in 2009 through a combination of ONMS and MMS support. Sanctuary staff have conducted the long-term monitoring program at Stetson Bank since 1998. The sanctuary research team maintains a database of the monitoring data, including historical records and non-digitized collections.



A diver attaches a new tag to a monitoring pin at East Flower Garden Bank.

Photo: FGBNMS

Sanctuary staff will continue to maintain the historical database that consists of long-term data acquired from annual photographic and video transects and quadrat images, fish surveys, and qualitative observations. Coral core (sclerochronology) and water quality measurements are also included in this database. Shallow coring of the coral cap at East and West Flower Garden Banks is conducted once every other year to assess the vitality of their coral communities. Water quality at East and West Flower Garden Banks is monitored quarterly.

Activity 3.2 Enhance and expand the long-term monitoring program within the sanctuary and surrounding banks.

Long-term monitoring activities will be enhanced to include surveys outside of the historical and current study areas on reef caps of both East and West Flower Garden Banks, as funding allows. These activities will include random belt transects collecting benthic cover and fish data. Monitoring techniques will be developed for the deepwater habitats utilizing ROV and diving technology. FGBNMS staff will also initiate monitoring programs, if possible, at surrounding reefs and banks. Of particular interest is Sonnier Bank, which has been heavily impacted by mechanical damage from anchoring, fishing, and the passage of Hurricane Rita. The recovery of Sonnier's biological community will be investigated if funding is secured. McGrail Bank is also a priority, as the crest of McGrail hosts a deep coral reef community that has not been previously monitored.

Though the water quality at East and West Flower Garden Banks is monitored quarterly, a regional picture of water quality is also desirable to maintain awareness of its effects on the sanctuary ecosystem. Discharge of pollutants from sources inside and outside the sanctuary may have potential detrimental impacts on sanctuary resources. The quality of coastal waters of the northern Gulf of Mexico is in decline due to pollutants associated with the discharge of major river systems, such as the Mississippi and Atchafalaya Rivers, and general coastal runoff throughout the region. Predominant current patterns direct much of this water away from FGBNMS, but minor changes in circulation patterns could bring contaminated water to the sanctuary. Monitoring the sources and effects of fresh, nutrient-rich, and/or polluted water on the sanctuary ecosystem will provide both valuable information regarding the wider region's effect on FGBNMS and heightened awareness of immediate water quality effects on the coral reef and coral-associated communities of the sanctuary. FGBNMS will pursue expertise and funding to address this more thoroughly.

Activity 3.3 Monitor sanctuary resources for human health concerns.

Dr. Tracy Villareal (University of Texas Marine Science Institute) reported the first encounter of the toxic dinoflagellate *Gambierdiscus toxicus* in algae sampled at the Flower Garden Banks in September 2006. At that time it was unknown whether ciguatoxins were entering the food web of the sanctuary. On February 5, 2008, the Food and Drug Administration (FDA) issued a Seafood Advisory targeting seafood processors purchasing grouper, amberjack, and related predatory reef species captured in the northern Gulf of Mexico. The advisory was issued in response to the FDA's concern over a number of recent outbreaks of ciguatera fish poisoning (CFP) that had been traced to fish from the vicinity of the sanctuary. The FDA considers CFP a likely hazard for hogfish, grouper, and snapper 'species of concern' captured within 10 miles of the sanctuary, and amberjack, barracuda and other pelagic 'species of concern' captured within 50 miles of the sanctuary.

FGBNMS staff and cooperating researchers will seek funding and support to seasonally sample algae and fish communities to monitor the presence and levels of ciguatoxin and the potential threat to humans through consumption of fish caught in the vicinity of FGBNMS. If funding is identified, algae will be sampled through SCUBA operations and fish tissue samples will be collected by partnering with the fishing community. Sanctuary staff will also pursue expertise and funding to monitor for presence of mercury and other heavy metals in fish communities.

Activity 3.4 Continue to conduct monitoring in response to natural and human-induced events.

The FGBNMS research team will continue to respond to and document episodic events of coral disease, bleaching, and hurricane effects on the sanctuary. Direct anthropogenic impacts, such as anchoring and oil spills, are also events that require a response plan and immediate documentation. Vessel support by the R/V *Manta* will greatly enhance the ability to quickly respond to such events, which had not been possible in the past. Once on site, SCUBA surveys will be conducted to monitor shallow regions (< 130 feet), and when needed, ROV surveys will be conducted in deeper water areas (> 130 feet).

Activity 3.5 Establish FGBNMS as a sentinel site to monitor climate change and ocean acidification.

Research on climate change has projected decreases in ocean pH and concomitant acidification of the ocean, increasing water temperatures and sea level rise. The location and biological assemblage of FGBNMS situates this sanctuary as an ideal sentinel site for monitoring the impacts of climate change on coral communities. The corals of FGBNMS, including *Acropora palmata*, are at the northern edge of their natural range, and as such, are ideal for monitoring the effects of forecasted changes in ocean chemistry and sea temperature. FGBNMS staff have prioritized the organization of a baseline of physical and biological oceanographic data relevant to understanding the local effects of ocean acidification. Data gaps and research needs will be identified, and research partnerships formed, to clarify the dynamics of climate change on sanctuary resources.

RM.4 Implement a process to evaluate the impacts of fishing and diving.

The sanctuary was established primarily to provide protection for the significant marine resources of the Flower Garden and Stetson Banks. The sanctuary must also provide for public use of its resources, as long as those activities are compatible with the primary mandate of resource protection. However, it has become clear from public comment that there is concern over the potential impact of some uses on the sanctuary.

Fishing and diving activities may impact sanctuary resources directly (physical impacts to the reef) and indirectly (removal of species that are key to ecosystem functioning and changing fish behavior through diver interactions). These activities have the potential to negatively impact and threaten the natural living resources of FGBNMS. The influence of fishing and diving activities on FGBNMS is not well documented, but concerns are mounting. Specific fishing activity concerns for FGBNMS include: targeted fishing efforts that could impact reef and pelagic fish populations; focused fishing during spawning aggregations; injury to corals and other organisms by lost and discarded fishing gear; and discarded fishing bycatch. Diving activity concerns include injury to corals and other organisms, and harassment of fishes and sea turtles to the point of significantly altering their behavior.

Fishing was identified as a primary issue of concern during the public scoping process. There is a perception by some long-time observers that the number and size of certain prominent fish species have declined in recent years. The sanctuary advisory council also identified fishing impacts as a priority issue and created a subcommittee to explore management strategies to address the concerns. The subcommittee identified an urgent need for additional detailed information about fishing and fish populations in order to establish recommendations for management action. It became clear that

existing data sources (fish landings, etc.) are inadequate to determine how or if existing levels of fishing and diving activity negatively impact sanctuary resources. To address this issue, the council reached consensus in April 2007 to recommend that the sanctuary design an experiment to investigate the impact of these activities. The experimental design will include the establishment of research areas in which fishing and diving will be restricted, and allow for comparison to similar areas that are unrestricted. Two workshops (July 2007 and April 2008) were conducted to explore the concept of such research areas. Participants from the workshops concluded that the establishment of controlled closure areas was the most direct and efficient method to determine potential impacts from fishing and diving activities. In September 2007, the sanctuary advisory council approved and forwarded to sanctuary management fishing impact strategies proposed by the subcommittee, including a recommendation for the establishment of an experimental fishing closure. The advisory council recommended that the study include time-limited access restrictions for fishing and diving within portions of the existing boundaries of FGBNMS.

The utilization of areas closed to fishing or diving for the purpose of research or management can be highly controversial. However, the need for definitive information on the impacts of these activities is necessary for future management of the sanctuary. Significant research questions exist at FGBNMS that can only be addressed by establishing research areas as controls. Therefore, NOAA believes, based on the recommendation of the sanctuary advisory council, that the research area concept should be further explored through a public review process. The advisory council recommendation included a number of proposed conditions that should accompany research area designation. The full scope of the council recommendation is as follows:

- Immediately implement a voluntary vessel registration system to begin to determine the level of fishing and diving activity within the sanctuary prior to management action.
- Compile all available data on vessel use activity within the sanctuary. Work with NOAA Office for Law Enforcement to obtain relevant information on commercial fishing activity acquired through the Vessel Monitoring System (VMS) program and other sources.
- Based on success of voluntary vessel registration system, consider the implementation of a sanctuary regulation requiring mandatory vessel registration in order to conduct activities within the sanctuary. This future regulation would be designed to align with other NOAA vessel registration requirements.
- Establish a monitoring program to evaluate fish and coral communities within areas proposed for experimental management. The monitoring program should be initiated at least one year prior to the implementation of the research areas.
- Establish a research program to determine the impacts of fishing and diving within the sanctuary through the use of appropriately placed research areas. The research areas will serve as control locations within which fishing and diving activities may be controlled. The boundaries of the research areas will be determined through a public process that will include sanctuary advisory council members, identified experts and stakeholders. The research areas should not be implemented until at least one year after the effective date of the implementation of the regulation to require mandatory vessel registration, and at least one year of baseline monitoring data has been acquired.
- Continue and enhance research to identify spawning aggregations, critical habitat and sensitive features within the sanctuary that may be impacted by fishing and diving activities.

- A program must be in place to monitor and enforce compliance with the sanctuary regulations relating to the experimental closure.
- Any experimental closure will terminate after eight years unless further action is taken by NOAA.

Activity 4.1 Establish a public process through the sanctuary advisory council to evaluate and provide recommendations for the establishment of research control areas within the boundaries of the East Flower Garden, West Flower Garden and/or Stetson Banks to investigate the potential impacts of fishing and diving.

To more extensively consider the utilization of research control areas in FGBNMS, the sanctuary advisory council voted in January 2009 to establish a research area working group. The working group will be led by members of the advisory council but will include the broad expertise that will consist of, but not be limited to, commercial fishers, recreational fishers, divers, researchers, law enforcement and other state and federal agency representatives. This group will be tasked to comprehensively examine the concept of and potential designs for the designation of research areas in FGBNMS as part of an experimental design to investigate the impact of fishing and diving, and will also develop recommendations for the full sanctuary advisory council to consider.

The areas to be evaluated in this process will be limited to the East Flower Garden, West Flower Garden and Stetson Banks. Areas under consideration for sanctuary expansion will not be included in the experimental design. Recognizing that the potential scale of impacts is different for fishing as compared to diving, the experimental design to evaluate those impacts will also be different. The research design to determine the impact of fishing should include control areas large enough to discern ecosystem level impacts (an entire bank or entire habitats within a bank); whereas the control areas needed to determine impacts of diving will be much smaller (portions of diveable areas within a bank). It will not be necessary to control diving access on an entire bank because potential impacts of non-consumptive diving are localized within an area, usually associated with mooring buoys. Therefore, the placement of mooring buoys will be utilized to investigate the potential impacts of recreational diving.

Activity 4.2 Establish and implement a biological resource monitoring program within the sanctuary for fish and benthic communities prior to establishment of research areas.

In order to evaluate the effects on sanctuary resources (fish and coral communities) of potential experimental management, NOAA would design and implement a biological monitoring program to assess any changes to fish and invertebrate communities inside and outside of the research areas should these areas be designated as a result of a public process. This monitoring program would have to be in place at least one year prior to designation of the research areas in order to provide adequate baseline data in advance of experimental management actions. The monitoring program will include the assessment of fish populations associated with representative habitats affected by the research area designations (i.e., coral reef, coral communities, algal reef and deepwater coral areas). The monitoring program design must provide statistically valid data in order to compare populations inside and outside the research areas and over time. Monitoring will continue at regular intervals throughout the experimental time frame.

Activity 4.3 Develop and implement an analysis to determine potential socioeconomic impacts of implementing a research area within FGBNMS.

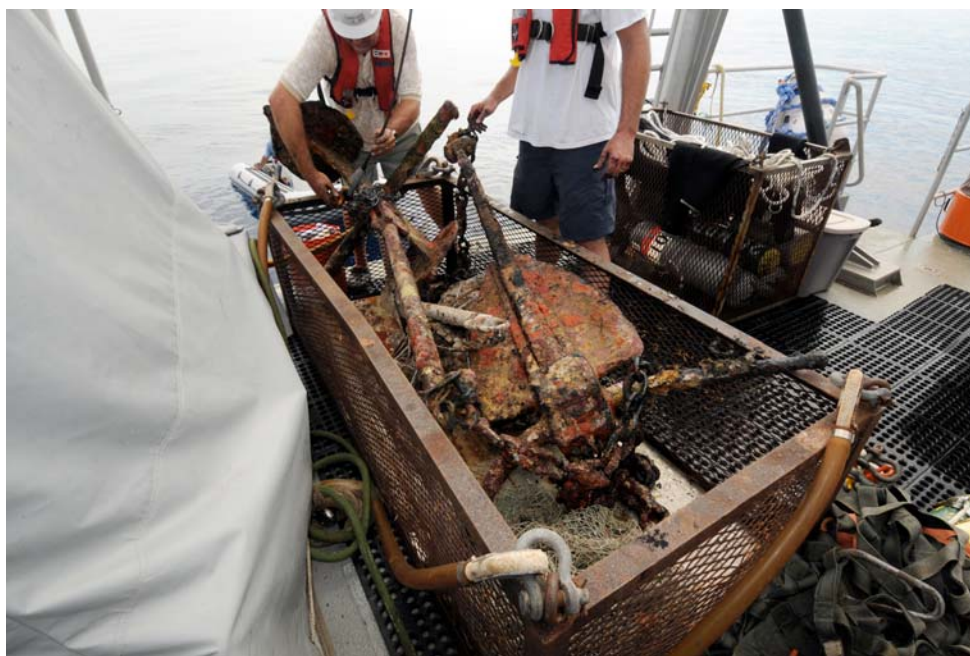
A socioeconomic study will be conducted to provide information on resource use as it relates to sanctuary expansion and the use of experimental closures to evaluate fishing and diving impacts. Additional socioeconomic studies, as needed, will be completed to evaluate resource use. Interviews with resource users, primarily commercial and recreational fishers and recreational divers, among other methods will contribute to our understanding of visitor use.

Activity 4.4 Conduct an analysis of possible alternatives for the establishment of a research design to determine impacts of fishing and diving.

A working group of the sanctuary advisory council will develop and present to the council a set of research area alternatives. Following recommendations of the council, sanctuary staff will conduct an alternatives analysis for the purpose of preparing a draft environmental impact statement, available for public comment, for any proposed research areas.

RM.5 Identify and evaluate ongoing and potential threats to sanctuary resources.

During the management plan review process, a number of issues were identified as having the potential to threaten the future health of sanctuary resources. Many of these issues are discussed in the FGBNMS State of the Sanctuary Report (2006) and the FGBNMS Condition Report (2008). Of these, three were identified as posing immediate threat to the sanctuary, and should be specifically addressed in this management plan. They are: marine debris, pollutant discharge, and invasive species.



Removal of marine debris from the sanctuary. Photo: FGBNMS

Derelict fishing gear and other marine debris are problems throughout the world ocean. Marine debris has been documented on all banks within FGBNMS, but is most concentrated at Stetson Bank. The source of the debris is primarily from fishing and boating activities. Marine debris can negatively impact reef ecosystems by entangling animals and “ghost-fishing” (continuing to catch

fish after the gear has been abandoned), as well as by degrading reef habitat through scouring. Pollutants, such as mercury and hydrocarbons, from boating and industry sources, also have the potential to impact sanctuary resources. Finally, ecosystem integrity of FGBNMS is threatened by the arrival and establishment of invasive species. Research will target these three areas, their current impacts, and their potential for synergistic impacts on the sanctuary ecosystem.

Activity 5.1 Assess the accumulation and impacts of marine debris.

Recreational and commercial fishing occur within and in the vicinity of the sanctuary. Shrimp trawl nets, boat anchors, twisted metal and fishing line litter the surface of Stetson Bank and the deeper regions around the Flower Garden Banks. The presence of derelict fishing gear and other marine debris at Stetson and East and West Flower Garden Banks has been reported by divers and documented through ROV habitat characterization surveys. The mapping and assessment of marine debris and its impacts on sanctuary resources will directly inform management decisions, whereas the removal of debris will help protect and restore the impacted reef habitat. Sanctuary staff will conduct opportunistic research on the occurrence, accumulation and impacts of marine debris within FGBNMS, as well as other hard-bottom habitats in the northwestern Gulf of Mexico.

Activity 5.2 Continue to identify presence and behavior of invasive species.

Invasive species, such as orange cup coral (*Tubastraea coccinea*), have already appeared in the sanctuary. Though mechanisms of recruitment of invasive species are still unknown for the sanctuary, there is a possibility that the proximity of artificial structures aids in the dispersal of invasive species. It is essential that sanctuary staff gather more scientific information on the presence, mechanism of dispersion, and impacts of invasive species in FGBNMS. A more thorough understanding of this issue will enable sanctuary staff to develop a response plan to manage the impacts of invasive species on sanctuary resources. Sanctuary staff will also develop collaborations to enhance early warning capabilities (e.g., Texas Parks and Wildlife Department, oil and gas industry, MMS) to address emerging threats such as the increasing number of Pacific lionfish (*Pterois* spp.) in the Caribbean and tropical Atlantic.

RM.6 Develop partnerships with local, national, and international researchers and organizations to enhance sanctuary research and monitoring programs.

FGBNMS is composed of reef communities that are unique to the Gulf of Mexico (e.g., coral-sponge communities, mesophotic coral communities) with location-specific research questions that could allow for comparison to other reef systems in the region, in other parts of the U.S. EEZ, and elsewhere in the world. Research and monitoring programs are dependent on outside expertise and investment. FGBNMS staff will continue current partnerships with research collaborators and institutions, while developing new partnerships in line with sanctuary research priorities. Sanctuary staff is able to offer the R/V *Manta* for charter or at no cost to facilitate research activities within FGBNMS and on surrounding banks in the northwestern Gulf of Mexico.

Activity 6.1 Collaborate with national and international scientists, agencies and institutions to conduct research on priority issues.

To accomplish research objectives, sanctuary staff will develop an annual research priorities plan and solicit outside researchers to conduct projects to address identified issues. Memoranda of Agreement (MOA) can be developed to establish the details of collaborative partnerships. Providing R/V *Manta* ship time for priority research projects is one method to ensure researchers have the

ability and flexibility to conduct studies at FGBNMS. Access to field equipment, lab space, and office support are other attractive features available to researchers.

Table 7: Estimated Costs for the Research and Monitoring Action Plan

Activity	Estimated Cost (\$000)					Total Estimate 5-Year Cost
	YR 1	YR 2	YR 3	YR 4	YR 5	
(1.1) Reproductive ecology	*5	*5	*5	*5	*5	25
(1.2) Recruitment dynamics	*0	*0	*0	*0	*0	*0
(1.3) Trophic interactions	*0	*0	*0	*0	*0	*0
(1.4) Connectivity	*10	*10	*10	*25	*25	80
(2.1) Physical & habitat mapping	15	25	25	30	30	125
(2.2) Biodiversity assessment	0	0	0	0	0	0
(2.3) Geological characterization	0	50	0	150	0	200
(2.4) Oceanographic assessment	*0	*0	*0	*0	*0	*0
(3.1) Current monitoring	200	220	242	266	292	1,220
(3.2) Expansion of monitoring	20	40	60	80	100	300
(3.3) Human health factors	5	5	5	5	5	25
(3.4) Event response	5	5	5	5	5	25
(3.5) Sentinel site	*0	*0	*0	*0	*0	*0
(4.1) Research area working group	10	10	10	0	0	30
(4.2) Monitoring program for baseline data	150	165	182	200	220	917
(4.3) Socioeconomic study	15	150	15	0	0	180
(4.4) Research area alternatives analyses	0	0	0	15	15	30
(5.1) Marine debris	2	2	2	5	5	16
(5.2) Invasive species	2	2	2	2	2	10
(6.1) Research collaboration	0	0	0	0	0	0
Total Estimated Annual Cost	439	689	563	788	699	3,183

*Will require outside funding in addition to amount indicated (source not yet identified).

Note: Labor and vessel cost estimates are incorporated in the Operations and Administration Action Plan.

Table 8: Performance Measures for Research and Monitoring Action Plan

Research and Monitoring Action Plan Activity	Performance Measure	Baseline	Description	Link to National Program Performance Measures
Activity 3.2 Enhance and expand the long-term monitoring program within the sanctuary and surrounding banks.	By 2014, FGBNMS staff will develop and implement a monitoring plan for Sonnier and McGrail Banks, if they are added to the sanctuary during the sanctuary expansion concept under consideration.	There are currently no monitoring plans in place since the decision to expand FGBNMS boundaries has not been made.	n/a	Monitoring
Activity 3.2 Enhance and expand the long-term monitoring program within the sanctuary and surrounding banks.	By 2014, FGBNMS staff will develop a monitoring plan for each of the new areas under consideration in the boundary expansion concept, if applicable.	There are currently no monitoring plans in place since the decision to expand FGBNMS boundaries has not been made.	n/a	Monitoring
Activity 3.2 Enhance and expand the long-term monitoring program within the sanctuary and surrounding banks.	By 2012, the water quality monitoring program will expand to include three new areas under consideration in the sanctuary expansion concept (Sonnier, Geyer, and Bright Banks), if applicable.	At East and West Flower Garden Banks physical samples are collected quarterly for off-site biological monitoring (nutrients, chlorophyll). At East and West Flower Garden and Stetson Banks, there are currently moored stations continuously recording temperature and salinity, with data retrieval occurring quarterly.	Multi-parameter water monitoring systems will be deployed by divers on Sonnier, Geyer, and Bright Banks.	Water Quality (PART)
Activity 4.1 Establish a working group of the sanctuary advisory council to comprehensively examine the concept of and develop potential designs for a research (experimental closure) area in FGBNMS.	By 2011, FGBNMS staff will begin a public process to examine the research area concept.	The FGBNMS sanctuary advisory council has made a recommendation to the FGBNMS Superintendent to explore the concept of research areas. A formal public process to consider this action has not yet begun.	n/a	n/a
Activity 5.1 Assess the accumulation and impacts of marine debris.	By 2011, FGBNMS staff will have developed a marine debris monitoring program for East and West Flower Garden Banks, and expanded the efforts in Stetson Bank.	Stetson Bank has been initially assessed for the presence of marine debris.	Monitoring for marine debris would include mapping the location of debris, identifying impacts and sources of debris, surveying the accumulation of debris and removing the debris when feasible.	Monitoring